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Chronophilia; or, Biding Time in a Solar System

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Abstract Having evolved in a dynamic solar system, all life on earth has adapted to and depends on recurring and repeating cycles of light, heat, and gravity. Our sleep cycles, reproductive cycles, and emotional cycles are all linked in varying ways to planetary motion even though we continually disrupt, modify, or extend these cycles to go about our personal and collective business. This essay explores how our sense of time is both physiological and cultural, with deep ramifications for confronting such challenges as jet lag, navigation, calendar construction, shift work, and even life span. Although chronobiologists have posited the existence of a *Zeitgeber*, or external master clock that serves to reset our internal clocks, it has become clear that any master clock relies as much on natural elements (such as a rising sun) as cultural elements (such as an alarm clock). Moreover the "circa" of *circadian* rhythms, suggests that our activities and emotions recur, not in exact twenty-four-hour cycles, but in more plastic and approximate cycles that, according to circumstance and individual, may span somewhat longer or shorter periods than one earthly rotation. Or as one chronobiologist explains, "Any one physiologic variable is characterized by a spectrum of rhythms that are genetically anchored, sociologically synchronized . . . and influenced by heliogeophysical effects." As we contemplate faster and further travel and other activities that disrupt our biorhythms, we need to develop greater awareness of *chronophilia*, our attachment to rhythm, our love of familiar time.

Keywords chronobiology, biorhythm, circadian, desynchrony, jet lag, shift work, sense of time

Even before the newborn infant takes his or her first gasps of air, he or she has settled into recurring patterns of rest and activity. In the last stages of pregnancy, an expectant woman easily detects fetal movements that may include twists, turns, and kicks, and such activities do not always coincide with the woman's own rest patterns. Revealing are the answers received by a pregnancy self-help site that queried its readers about whether their fetuses slept while they slept. As one respondent explained, "Liv had definite sleep and wake patterns in the womb that she kept after she was born. She slept when I slept. . . . Toward the end I could tell the difference between her awake movements and her sleep stretches." Another added, "I usually feel her every night when I get settled in bed, and off and on in the afternoon. I think she's most active in the evening

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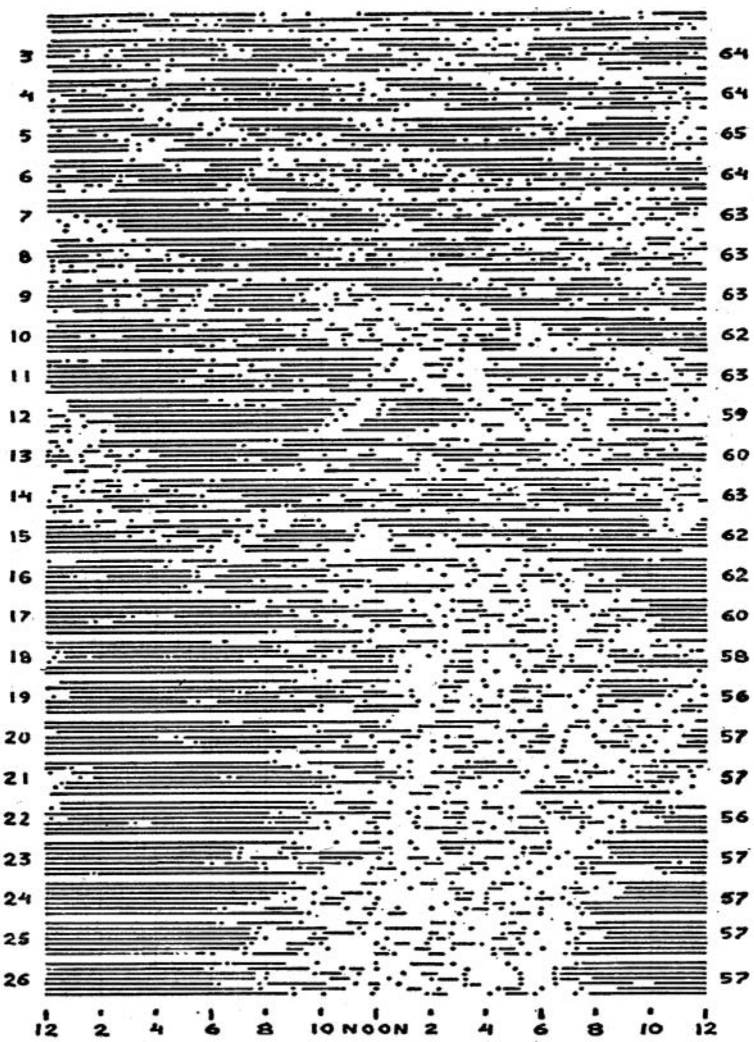


Figure 1. A healthy baby's rest and activity periods during the first 26 weeks of life. Horizontal lines represent sleep; breaks represent wakefulness. Left axis lists weeks from birth; right axis lists percentage of time sleeping; bottom axis lists time of day. From Nathaniel Kleitman, *Sleep and Wakefulness* (Chicago: University of Chicago Press, 1939: 137).

though." A third reader noted simply, "Mine had dance parties at 2am everyday."[1] Author of the 1939 classic *Sleep and Wakefulness*, Nathaniel Kleitman also wondered about human activity cycles, focusing at one point on newborns, most of whom initially showed rather erratic resting patterns, and not until the seventh or eighth week of life would they begin to sleep for extended periods. Kleitman found that only by the sixteenth or seventeenth week would a healthy baby begin to sleep through the night and start repeating this cycle in regular twenty-four-hour intervals (fig. 1). By tracking and then manipulating sleep cycles, as when he sought to follow other than twenty-four-hour days while living deep within a Kentucky cave, Kleitman may have been the first

1. Hellobee, "Does the Fetus Sleep When You Sleep?," boards.hellobee.com/topic/does-the-fetus-sleep-when-you-sleep/ (accessed May 1, 2018).

systematic investigator of desynchrony, the disorientation one feels after disrupting one's biological clock.[2]

Sleep cycles are just one of the many bodily rhythms around which people fashion their lives and their aspirations. Hormonal releases, digestive flows, bodily temperatures, and mental acuities also rise and fall each day in roughly daily or *circa-dies* cycles. Yet beyond circadian rhythms stemming from a rotating earth, there are also circannual rhythms stemming from an earth orbiting the sun so that people may, for example, gain body fat in fall and lose it in spring, to be repeated the following year when food supplies are plentiful or else scarce. Likewise, approximate twice-daily movements of ocean tides—two highs and two lows—modify marine ecosystems and so the twice-daily lives of people who depend on them. Approximate seven-year cycles of El Niño ocean currents modify weather patterns and so the human activities that depend on these patterns, as when fish harvests in Peru decline during El Niño years. Circa-monthly cycles mark the rising and falling ability of a woman's uterus to nurture a fertilized egg. And while we humans act on all of these cycles to bend them to our individual and collective needs, they are also pushed and pulled by a moon orbiting a rotating earth that with offset axis orbits around the sun. All life on earth has evolved over billions of years under repeating and recurring cycles of light, heat, and gravity. Ever since rudimentary creatures emerged from a primordial soup, every cell on the planet is by the darkness of night preparing for the sun to rise, and then by the bright light of midday is already preparing for the sun to set. Heaven's great orbs synchronize the very firing of our synapses.

Rarely are such cosmic forces felt more viscerally than when we step off a plane in Paris, having just arrived from New York. Supremely honed in one time zone, our body is suddenly thrust into another, with the consequences of jet lag as disconcerting as they are debilitating. Our attachment to a former time zone is both physiological and psychological, a *chronophilia* that requires significant adaptation in order to feel comfortable in our destination's new set of temporal rhythms. In what follows, I explore when desynchrony first became an issue, how people explained and addressed these and other biorhythmic disruptions, and what our attachment to rhythms mean to ourselves and those around us. My larger purpose is to point out just how far nature's rhythms have shaped human societies, revealing how we humans have in turn sought to shape these many little timepieces that are ticking in and all around us. Along with an affinity to our *topos*, each of us is intimately attached to our *chronos*.

Leaving One's Mind Behind

By most accounts, the first clear description of desynchrony appeared in 1919 when biplane navigator Arthur Brown recounted his experiences following that first transatlantic flight from Newfoundland to Ireland in just sixteen hours. "In our eastward flight

2. Kleitman, *Sleep and Wakefulness*, 137, 172–84.

of two thousand miles we had overtaken time, in less than the period between one sunset and another, to the extent of three and a half hours," Brown wrote.

> We were reluctant to rise at 7 A.M.; for our subconsciousness suggested that it was but 3:30 A.M. This difficulty of adjustment to the sudden change in time lasted for several days. Probably it will be experienced by all passengers traveling on the rapid trans-ocean air services of the future—those who complete a westward journey becoming early risers without effort, those who land after an eastward flight becoming unconsciously lazy in the mornings, until the jolting effect of the dislocation wears off, and habit has accustomed itself to the new conditions.[3]

Certainly many of the day's long-distance daredevil and cosmopolitan aviators also experienced time dislocations, be they Sacadura Cabral, Italo Balbo, Charles Lindbergh, Amelia Earhart, Jean Batten, or Kiku Nishizaki, who all hopped continents or oceans in a matter of hours or days to pioneer rapid long-distance routes. Circadian experts today claim that the symptoms of desynchrony only become evident when a person crosses more than one hour-long time zone per day, so that Wiley Post's and Harold Gatty's flight around the world crossing twenty-four time zones and lasting about eight days in July of 1931 undoubtedly brought on temporal disorientation together with the complications of crossing a dateline.[4] It turns out that Ferdinand Magellan's crew members were probably the first to experience the puzzling dateline shift when they circumnavigated the globe in the 1520s, arriving back to Portugal to find their diaries dating one day earlier than those of their comrades who stayed home. The explanation is that in their three-year westward voyage around the earth, by continually chasing the setting sun, the sailors experienced slightly shorter days and so tabulated one less sunset by the time they returned home, apparently losing one day—even if they likely experienced little circadian delirium.[5]

It is worth noting that crew members of modern container ships do occasionally complain about "ship lag." One second officer explains that after crossing the Pacific several times at speeds of around 21 knots (24 mph), his bouts of fatigue while on watch become so intense that he experiences the "near inability" to keep his eyes open and becomes "totally useless" for decision-making.[6] Yet early steamships rarely reached such speeds, with an average Atlantic crossing in 1850 requiring twelve days, and only by 1900 did they shrink in the fastest scenarios to around six or seven days, a speed that would still not cause much desynchrony by crossing just one time zone per day.

3. Brown, *Flying the Atlantic in Sixteen Hours*, 84–85.

4. Sack, "Clinical Practice.

5. Dan Heim, "The International Date Line, Explained," *LiveScience*, August 31, 2018, www.livescience.com/44292-international-date-line-explained.html/. A good overview of circadian rhythms is Winfree, *Timing of Biological Clocks.*

6. Malawwethanthri, "Fatigue and Jet lag," 26; see also Rodrigue, *Geography of Transport Systems*.

Unusual sleep patterns were certainly an issue on these oceanic voyages, but desynchrony was less the cause than that of being cramped in lower-class quarters while subsisting on crude diets, or else enjoying the euphoria of upper-class staterooms while readjusting from city schedules. As one historian describes life at sea for these first-class ticket holders, "Everyone throttled down into simpler, longer rhythms. Clock time barely mattered . . . passengers reverted to pre-industrial notions of time, measured out in vague approximations of the sun and night sky."[7]

Perhaps long-distance train passengers were really the first to suffer from serious time dislocation. But if it is true that railroads hastened the "annihilation of space and time," they did not impart much train lag, even for passengers moving directly east or west so as to magnify the effects of time-zone changes.[8] The first ambitious translongitudinal train lines reached from coast to coast across the United States in 1869 and across Canada in 1885. An express train from New York to San Francisco was then requiring about four days to move through four time zones, so that desychrony probably did not bother those passengers much.[9] The trans-Siberian line from Moscow to Beijing opened in 1916, and the trans-Australian line in 1917, but such trains likewise moved at speeds of about one time zone per day—lasting a week in Siberia and four days in Australia—thereby presenting no real nuisances in time dislocation. Even the Orient Express that whisked passengers from Paris to Constantinople in the 1880s (or in variants from London to Athens) required a minimum of about two and a half days to move across two to three time zones.[10] Thus, while train travel stimulated the establishment of discrete zones of time by linking distant towns with a single train schedule, trains did not move faster than the physiological ability to adjust to solar time. At 42 degrees north latitude (roughly that of Chicago or Rome), a one-hour time zone stretches about 770 miles east–west, which is therefore the distance a traveler needs to cover in a single day before experiencing desynchrony. Yet at higher latitudes—due to converging longitude lines—east–west travelers can cross a time zone in just a few hundred miles. A north–south journey, on the other hand, alters a person's daily exposure of sunlight, but not his or her twenty-four-hour rhythm. Such latitudinal considerations meant that polar travelers became even more attuned to the disruptions caused by rapidly crossing time zones.

By the 1920s, as hot air balloons were crafted into sophisticated, propeller-driven dirigibles, a new age of rapid transportation had begun, serving to offset circadian rhythms in earnest. In the decade before the *Hindenburg*'s 1937 tragedy, one source tabulates

7. Fox, *Ocean Railway*, 205–6. See also Keeling, *The Business of Transatlantic Migration.* Special thanks to Drew Keeling for pointing out Fox's passages.

8. Marx, *Machine in the Garden*, 194.

9. "1876 Express Train Crosses the Nation in 83 Hours," www.history.com/this-day-in-history/express-train-crosses-the-nation-in-83–hours (accessed July 17, 2017).

10. "The Truth behind the Legend: The Orient Express," www.seat61.com/OrientExpress.htm#Chronology/ (accessed January 5, 2018).

that 51,000 passengers were carried more than 1.25 million miles in hundreds of transcontinental, transoceanic, and around-the-world dirigible flights.[11] One dirigible enthusiast declared, "Large commercial airships show great promise as a safe means for bulk transport over world trade routes."[12] Airship passengers typically lifted off in the evening from one of dozens of airship ports, spent one or several nights in their floating berths, with some of them certainly getting out of synchrony with their former time zones. As one passenger on the *Hindenburg*'s New York flight a year before the famous tragedy explained, "This rapid translation from continent to continent across 3,000 miles of ocean left in me an uncanny sense of confusion. The mind had not been able to keep pace with the body. Less than sixty-two hours before I had been in middle Europe. In that time 106 of us had been transported across one-fourth of the globe and my body, so it seemed, had left my mind behind."[13]

The airship era also saw the first polar flight from Norway to Alaska in 1926, which took Umberto Nobile and crew nine days to cross and recross many longitude lines, finishing with a net displacement of ten time zones. But it was also true that airship travelers could lounge in comfort and sleep in real beds to help mitigate time zone readjustment.[14] The *Graf Zeppelin*'s popular Germany to Brazil prewar route that crossed five time zones in a few days meant its passengers suffered time dislocation but not as severely as would their heavier-than-air counterparts who traveled by airplane.[15] In fact despite the airship's tarnished reputation after 1937, the lighter-than-air dirigible was still being promoted in some circles as an appealing compromise between the steamship and the airplane in its ability to combine speed with relaxing comfort, so much so that the US Navy would maintain a small airship fleet until the 1960s.[16] This military strategy makes more sense after realizing that a few twenty-first-century entrepreneurs had begun constructing upgraded dirigibles in hopes of meeting the rising demand for low-carbon, modest-speed travel that offers stateroom accommodations and relief from jet lag.

Even if safer and faster airplanes were in wide use by World War II, most middle-income persons and the tens of thousands of soldiers who traveled between continents still did so on the water rather than in the air. But with the first regular commercial transatlantic flights beginning in 1956, when passengers sat ten hours inside a propeller-driven Douglas DC-7c, the six- to eight-hour time lag was becoming a much

11. "Lighter-Than-Air History: Rigid Airships," PeriscopeFilm, 1947, www.youtube.com/watch?v=tjtGB1wC_hY/ (accessed May 1, 2018).

12. "Lighter-Than-Air Ships," 258.

13. Airships.net, www.airships.net/hindenburg/flight-schedule/maiden-voyage/passenger-account/ (accessed May 1, 2018).

14. Rosendahl, *What about the Airship?*, 172.

15. Hiam, *Dirigible Dreams*, 143.

16. "US Navy Lighter-Than-Air (LTA)." Naval Airship Association, www.naval-airships.org/ (accessed May 1, 2018).

more common phenomenon.[17] By the next year, more people were crossing the Atlantic by airplane than by ship.[18] Awareness of chronophilia continued to multiply in this era of distant warfare, as when US Air Force pilots ferried troops across the Pacific to reach battlefields in Korea and then Vietnam. As one veteran pilot reminisced about his multiple C-141 flights between California and Asia, “after a few days of this we were pretty jet-lagged.”[19] With the advent in 1958 of such classic jetliners as the Boeing 707 and Douglas DC-8, the world had definitively entered the jet age—and one can add, the jet lag age. Or perhaps the melatonin age. Melatonin consumption accelerated after it was singled out in the 1980s as one of the few medications that could marginally sooth disrupted circadian cycles.[20] By 2016, air traffic controllers were counting some 2,500 flights crossing the north Atlantic in a single day, or about one flight every 35 seconds.[21] Today worldwide at any given instant, there are more than a million airborne travelers, many of whom are being pushed well beyond their temporal comfort zones.[22]

Jet-Lagged Nations

An early frequent flyer was Oklahoma’s Wiley Post who in the 1930s piloted his Lockheed Vega *Winnie Mae* across the United States and twice around the world, together with numerous regional flights, serving to stretch the limits of his bodily rhythms (fig. 2). Post also roared as far as he could into the upper atmosphere to test the first high-altitude pressure suits that with helmet and trousers resembled underwater diving gear without the leaded boots.[23] Long uninterrupted hours in the cockpit crisscrossing time zones brought on such drowsiness that Post was in the habit of tying a string between a wrench and his forefinger so that, when gripping both yoke and wrench, he would be yanked awake if nodding off and loosening his hold on either. Post also sought to adjust to his destination’s eating and sleeping schedules several days in advance of his departures. Moreover he found that, upon arrival, exposure to bright sunlight helped him get synchronized with local schedules, a technique that mimicked light therapies already popular by the 1920s.[24] Subsequent investigators found that sun exposure reduces the secretion of melatonin for helping reset the body’s clock.[25]

Before the jet era, the most common descriptor of rapid travel syndrome seems to have been “pilot fatigue” or perhaps “aircrew fatigue,” even if such weariness might

17. *Flight*, “Atlantic Journey.”

18. *New York Times*, “Jet-Shrunk World Awaits Tourist,” 445.

19. Baker, “C-130 Airlift in Vietnam.”

20. Arendt and Marks, “Can Melatonin Alleviate Jet Lag?” Consumption of melatonin in US adults doubled between 2007 and 2012; see Sanders, et al., “Aeromedical Aspects of Melatonin.

21. “Over the Ocean—Twenty-Four Hours of Transatlantic Flight.” *Flightradar24*, www.flightradar24.com/blog/over-the-ocean-24-hours-of-transatlantic-flight/ (accessed June 6, 2016).

22. Dubin, “This Is the Insane Number of Flyers.”

23. Maranzani, “Wiley Post Makes History.”

24. Luckiesh, *Artificial Light*.

25. Wever, “Der Einfluss des Lichtes”; Comperatore and Krueger, “Circadian Rhythm Desynchronosis.”

Figure 2. Repairs being carried out on the *Winnie Mae* after a nose-first crash at Flat, Alaska, during Wiley Post's around-the world-solo flight; July 1933. *Source:* Wiley Post-Flat, Alaska Collection, 1998-129-2, Archives University of Alaska, Fairbanks.

have arisen from many sources. The log-keeper of an airship class R34's first westward crossing of the Atlantic in 1919 noted that many crew members had become exhausted by the fourth and final day, with R34's main clock being moved an hour forward on five different occasions.[26] In Nobile's airship's flight over the pole in 1926, he called attention to "the deadly fatigue that had threatened to overwhelm me."[27] Such travel tales helped turn fatigue into a favorite research subject, when airships, aeroplanes, and autogiros (early helicopters) began lifting people into longer and higher journeys to the growing discomfort of all those aboard. One study observed that air passengers confronted long flight hours, incessant engine drone, gusty drafts, dehydration, exposure to thin air and cold temperatures.[28] The Harvard Fatigue Laboratory (1927–47) was established to test physiological responses under a variety of extreme conditions, with its first projects focusing on high-altitude stress and the human body's response to low pressure and oxygen deprivation.[29] This was also a period when self-experimentation was much in vogue, as when sleep researcher Kleitman pushed his own limits to go without rest, claiming to have stayed awake for over 180 hours—more than a week—"on more than one occasion" with a little help from benzedrine sulfate tablets, or *speed*, a remedy that became a favorite of drowsy World War II pilots.[30]

In fact the human stresses of air travel ushered in a whole new branch of medicine that investigated the causes and remedies of airplane-related maladies. Classics such as Harry Armstrong's *Principles and Practices of Aviation Medicine* (1939), which surveyed health issues linked to unusual temperature, pressure, and endurance, built upon the

26. Maitland and Kipling, *The Log of H.M.A. R34*.

27. Nobile, *My Polar Flights*, 83.

28. "What Is Pilot Fatigue?"

29. Harvard Fatigue Laboratory. socialarchive.iath.virginia.edu/ark:/99166/w6vm9kqn (accessed May 1, 2018).

30. Altman, *Who Goes First?*; Johnson, "'They Sweat for Science'"; Kleitman, *Sleep and Wakefulness*, 220; Rasmussen, *On Speed*, 53–86.

insights of forerunners such as Hubertus Strughold who tracked physiologies of pilots.[31] As an aside, it should be noted that Armstrong, a general in the US Air Force, helped recruit Germany's Strughold to the United States following World War II to contribute to the fledgling American space medicine program, even if Strughold was implicated in various projects involving human experimentation under the Nazis—projects Strughold denied any knowledge of despite significant evidence to the contrary.[32] Among other projects, Strughold had investigated how long-distance flights impaired a traveler's ability to reason and act efficiently. Other observations revealed that circadian displacement heightened one's pain sensitivity, emotional incontinence, and even susceptibility to hallucinations. Eastward flights were found more draining than westward ones, and older passengers suffered desynchrony's effects more severely. A London newspaper of 1961 referred to the discomfort brought on by air flight as the "Strughold Syndrome."[33]

Other labels for modernity's newest malaise were *time zone fatigue* and *flight dysrhythmia*, soon becoming an occupational disease for those who "are seldom physically at home in their residential time zones."[34] The National Aeronautics and Space Administration's (NASA) early experience with jet propulsion meant that it paid special attention to anything that might reduce a pilot's performance, as when it sent John Glenn around the earth three times in under five hours—even if Glenn experienced little circadian disruption by landing so quickly in the same time zone from which he lifted off.[35] By 1966, newspaper journalists were nominating "the Jet Lag" as responsible for making traveling baseball players "too logy for at least the first game in any given series."[36] Avoiding any reference to aircraft, the French christened this new syndrome *décalage horaire*—schedule shift—with the Japanese opting instead for *jisaboke* (時差ぼけ)—time difference blur. Sleep research had also become more relevant, as by tracking a sleeping person's brainwaves with electroencephalograms and realizing such waves followed distinct patterns, as during Rapid Eye Movement (REM) sleep. In 1971, NASA published an extensive bibliography of biorhythm research that included a long section on "Desynchronosis and Performance." Many of the entries listed were in Russian, which reported on the experiences of the cosmonauts.[37]

Not surprisingly, the widening effects of jet lag began shaping daily affairs or even world politics. In one anecdote, US Secretary of State John Dulles flew to Cairo in 1956 to speak with President Nasser about the American financing of the Aswan Dam. But owing to travel stress and time-zone shifts, Dulles had by his own account not been very smooth in negotiations; moreover upon returning to Washington and newly jet

31. Siegel et al., "Time-Zone Effects," 1–11.
32. Strughold, "Physiological Day-Night Cycle."
33. Campbell and Harsch, *Hubertus Strughold*, 94.
34. Laskowitz et al., "Civilian and Military Uses of Aerospace," 417.
35. Hauty and Adams, "Pilot Fatigue."
36. *New York Times*, "Long Hauls Are a Strenuous Part of the Long Season."
37. NASA Technical Reports Server, *Information Services*.

lagged while learning that the Egyptians had been buying Soviet arms, Dulles—to his later regret—impulsively canceled the deal thereby opening Egypt and Africa's doors to the Soviets who stepped in to finance the project.[38] The hazards of conducting high diplomacy under jet lag were further demonstrated by a 1972 conversation in Moscow between Richard Nixon and Leonid Brezhnev in which Nixon agreed that "The hardest thing in these trips is the time difference. The first days you simply don't know when to get up and when to go to bed." In a reciprocal visit to Washington some months later, Brezhnev was himself reportedly rather incoherent on various social occasions.[39] Jet lag made its mark in other sectors as well, such as sports, and not just in baseball. When gold medalist diver Greg Louganis was competing at a meet in the Soviet Union in 1971, he credited his midair disorientation—and near-fatal head slam against the ten-meter platform—to the effects of jet lag.[40] Jockeys likewise began paying special attention to time-zone shifts, even if their racehorses apparently recovered more quickly than they did after both were loaded onto 747s and airlifted across oceans.[41]

One can begin to appreciate the myriad direct and indirect ways that the power of chronophilia was inserting itself into the world of diplomacy, sports, business, tourism, and the military. Little surprise that "jet lag" hotels cropped up in destination cities for meeting demands of travelers seeking to reproduce their departure cities' ambient conditions, offering sundry remedies to smooth time-zone transitions. A Tampa hotel now provides a "dawn simulator" that wakes up guests at a selected time with increasing light and music.[42] A Dubai jet lag service offers full facials with "acupressure of meridian points."[43] A restaurant in London includes a meal option rich in tryptophan and laced with melatonin.[44]

Adventures in Chronobiology

Although the scientific field of chronobiology did not blossom until the 1960s, reflecting the growing experience with circadian displacement, the recognition that plants, animals, and people obey remarkably rhythmic cycles is hundreds of years older. There also seems to have been a proclivity for investigating biorhythms within caves, which became favorite laboratories for supplying absolute darkness and shielding the sun's daily rays. The observation that flowers opened and closed in regular solar intervals or tracked the sun across the sky led eighteenth-century natural philosopher Jean-Jacques de Mairan to wonder how such plants might react in the absence of sunlight. As a devotee

38. Foster and Kreitzman, *Circadian Rhythms*, 24–25.

39. Caldwell and Hocking, "Jet Lag."

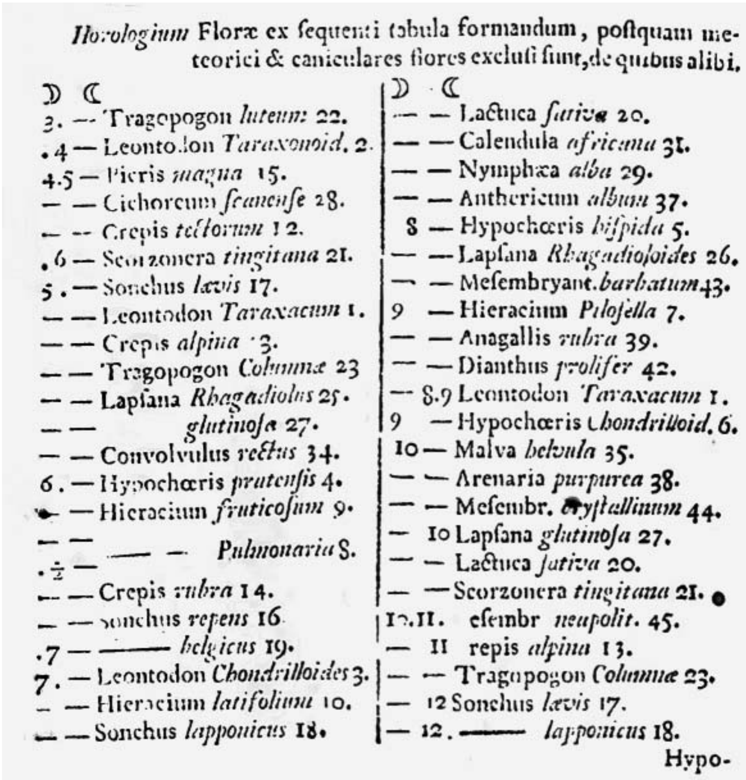
40. Scanlon and Ehret, *Cure for Jet Lag*, 10.

41. "Air Horse One—How Thoroughbred Jet Setters Beat Jet Lag," www.thehorsecomesfirst.com/ (accessed May 1, 2018).

42. Vora, "Hotels That Help You Fight Jet Lag."

43. Butler, "Beat the Jetlag."

44. Sahota, "In London, Hotels Help Guests Combat Jet Lag."



Horologium Floræ ex ſequenti tabula formandum, poſtquam meteorici & caniculares flores excluſi ſunt, de quibus alibi.

☽	☾		☽	☾	
3.	—	Tragopogon *luteum* 22.	—	—	Lactuca *ſativa* 20.
.4	—	Leontodon *Taraxonoid.* 2.	—	—	Calendula *africana* 31.
4.5	—	Picris *magna* 15.	—	—	Nymphæa *alba* 29.
—	—	Cichoreum *ſcanenſe* 28.	—	—	Anthericum *album* 37.
—	—	Crepis *tectorum* 12.	8	—	Hypochœris *hiſpida* 5.
.6	—	Scorzonera *tingitana* 21.	—	—	Lapſana *Rhagadioloides* 26.
5.	—	Sonchus *lævis* 17.	—	—	Meſembryant. *barbatum* 43.
—	—	Leontodon *Taraxacum* 1.	9	—	Hieracium *Piloſella* 7.
—	—	Crepis *alpina* 13.	—	—	Anagallis *rubra* 39.
—	—	Tragopogon *Columnæ* 23	—	—	Dianthus *prolifer* 42.
—	—	Lapſana *Rhagadiolus* 25.	—	8.9	Leontodon *Taraxacum* 1.
—	—	*glutinoſa* 27.	9	—	Hypochœris *Chondrilloid.* 6.
—	—	Convolvulus *rectus* 34.	10	—	Malva *beloula* 35.
6.	—	Hypochœris *pratenſis* 4.	—	—	Arenaria *purpurea* 38.
[illegible]	—	Hieracium *fruticoſum* 9.	—	—	Meſembr. *cryſtallinum* 44.
—	—	— — *Pulmonaria* 8.	—	10	Lapſana *glutinoſa* 27.
.½	—		—	—	Lactuca *ſativa* 20.
—	—	Crepis *rubra* 14.	—	—	Scorzonera *tingitana* 21.
—	—	Sonchus *repens* 16	10.11.		eſembr *neapolit.* 45.
.7	—	——— *belgicus* 19.	—	11	repis *alpina* 13.
7.	—	Leontodon *Chondrilloides* 3.	—	—	Tragopogon *Columnæ* 23.
—	—	Hieracium *latifolium* 10.	—	12	Sonchus *lævis* 17.
—	—	Sonchus *lapponicus* 18.	—	12.	——— *lapponicus* 18.

Hypo-

Figure 3. Linneaus's table of plant species for constructing his Horologium Florae, arranged by the hour when flowers begin to bloom each day (from 3:00 A.M. to 12:00 noon on this page). From: Caroli Linnaei, *Philosophia Botanica* (Stockholm: Kiesewetter, 1751: 274).

of Newton, de Mairan's real passion was understanding attractions between astronomical bodies as well as the nature of sunlight, which he investigated at one point in 1729 by watching touch-me-nots (*Mimosa pudica*) orient their leaves skyward every twenty-four hours even when placed for some days inside a dark cave. In recounting this curious daily rhythm, he wondered how this plant could "feel the sun without seeing it."[45] This occult ability to detect invisible phenomena would be taken up by other eighteenth-century investigators such as Lazzaro Spallanzani, who postulated a "new sense" in bats that allowed them to navigate flawlessly around obstacles in dark caves even when blindfolded.[46] For his part, Linnaeus noted that the flowerings of various plant species occurred with such precision around a twenty-four-hour cycle that a living flower-clock might be assembled by arranging key species according to their flowering sequence in a life-size timepiece, what he called an "Horologium Florae" (fig. 3). Using Carl Linnaeus's descriptions, a few intrepid gardeners eventually assembled this living clock, finding it to keep reasonably accurate time.[47] Subsequent naturalists built on these investigations of organismal periodicity, including Darwin, who at one point turned his attention

45. de Mairan, "Observation botanique."

46. Hall, "Can Bats See with Their Ears?"

47. Linnaeus declared that "the time also of solar flowers opening and shutting should be made out in every climate, that any one, without the help of a clock, or seeing the sun, might know the time of the day" (*Elements of Botany*, 402).

to a class of "sleeping plants" and their daily relaxing and flexing of leaves. Still other researchers of the day focused on the mysteries of animal torpor and hibernation, proposing a range of explanations for these seasonal drowsy states.[48] As one naturalist declared, "hibernation is, in every respect, but the parallel of ordinary sleep, varying only in force and duration." Such observations revealed that most creatures were deeply attached to their own temporal rhythms.[49]

A few circadian researchers began supposing that each organism was endowed with an internal clock, with their key question hinging on whether there were one or many such clocks.[50] But the concept of physical, ticking timepieces imbedded in organisms was hard to accept, with one biologist finally declaring in 1959 that physiological clocks seemed "to be everywhere, and yet nowhere."[51] A leader in the field, Jürgen Aschoff, had proposed the existence of a *Zeitgeber*, or master pacesetter that served to synchronize bodily clocks from without, and which relied on natural and social stimuli. Yet Aschoff's followers wondered about the precision of exogenous as well as endogenous clocks, their exact locations, or whether they might represent a kind of holy grail of chronobiology.[52] John D. Palmer nonetheless dedicated his 1976 textbook about biological rhythms to students entering the field—"may one of you find the clock"[53]—even if it had become quite clear that a central, ticking organic timepiece was a rather crude model of what really guided recurring patterns of sleeping, breathing, digesting, heating, cooling, beating, secreting, and thinking. In the world of long-distance air travel, it was also clear that recovering from the desynchrony of jet lag required more than simply resetting a body's clock: jet lag recovery was akin to resetting and resynchronizing a room full of clocks, all ticking at a different pace, all to a different hour. The fact that our many symbionts living on and in us, from head lice and eyebrow mites to tapeworms and gut bacteria, are themselves ticking to their own circadian rhythms, further complicates our easy recovery from rapidly switching time zones.[54]

But one thing was becoming clear from all this sleep research. No matter how much they tried, researchers such as Kleitman and Aschoff could not distort human activity rhythms much beyond their usual daily cycles. After weeks of living in caves, for example, human volunteers could be made to live twenty-hour days, and even twenty-eight-hour days. Yet when left to their own devices and allowed to sleep as long as they wanted in the absence of any periodic light cues, volunteers would spontaneously adopt *twenty-five-hour* cycles: after spending weeks or months in caves or bunkers blocked from the sun, or in Spitzbergen's darkness, volunteers tended to add one extra

48. Darwin, *Power of Movement within Plants*.

49. Marshall Hall, quoted in Johnson and Johnson, *Medico-Chirurgical Review*, 83.

50. Daan, "A History of Chronobiological Concepts."

51. Brown, "Living Clocks."

52. Foster and Kreitzman, *Rhythms of Life*, 60–81; Roenneberg and Merrow, "Entrainment of the Human Circadian Clock"; Cambrosio and Keating, "Disciplinary Stake."

53. Palmer, *Introduction to Biological Rhythms*, v.

54. Rijo-Ferreira et al., "*Trypanosoma brucei* Metabolism Is under Circadian Control."

hour to their day beyond an earthly rotation. This longer, twenty-five-hour "cave day" meant that after a month or so, the subjects' "cave calendar" would begin to lag one day behind the civilian calendar.[55] Such observations implied that under our normal living conditions, each of us may actually be depriving ourselves of about one hour of sleep each day.

One now realizes that by utilizing "circa" in their terms, chronobiologists studying circadian rhythms were emphasizing that organisms manifest *approximate* twenty-four-hour cycles, which under a cave's artificial conditions of societal and sunlight absence typically stray an hour beyond a solar day. Organisms do not live their lives by a metronome, since daylight hours vary continually across the year, and since a year is composed of a fraction of days—365.24 to be exact. Without continual circadian readjustment, our days would begin to march ahead of our seasons to the tune of .24 days, or 6 hours per year (some 2 to 3 days per decade). These continually varying regimes of sunlight and seasons mean that our bodily rhythms require continual fine-tuning, which is carried out by stimuli within and beyond our bodies, to include our social system as well as our solar system.[56] Or, as a leading chronobiologist of the new generation, Franz Halberg, summarized a lifetime of research, "Any one physiologic variable is characterized by a spectrum of rhythms that are genetically anchored, sociologically synchronized . . . and influenced by heliogeophysical effects."[57] Stated differently, each of us is modestly but chronically jet-lagged, and it is only through a three-way stimulus of our genes, our society, and the rising sun, which prevents us from sleeping in each day.

Collective Desynchrony

One thus realizes that the whole spectrum between nature and nurture is responsible for steering our bodily rhythms. The cosmos produces daily impulses and seasonal variations of light and heat around which our DNA evolves, even as these energy pulses are pushed or shifted according to social need and custom. As one such custom, many of us adjust our clocks each year in a ritual of "saving daylight" to shift more sunlight to the evening during long summer days. But each time we *fall behind* or *spring ahead* by switching our clocks one hour, we collectively suffer jet lag, thereby requiring at least one day for our bodies to adjust to the new time. Not surprisingly, opinions have been deeply divided over this biannual shift of the clock ever since Robert Pearce in the early 1900s proclaimed its advantages to the British Parliament. Criticism of Daylight Saving Time (DST) surrounded parliamentary debate, and continues to this day, usually following predictable demographic patterns from urban to rural.[58] A recent Australian referendum, for example, showed that city folk generally favor adopting DST, whereas their

55. Lewis and Lobban, "Dissociation of Diurnal Rhythms"; Aschoff, "Circadian Rhythms in Man"; Wever, *Circadian System of Man*.

56. Halberg, "Physiologic Twenty-Four-Hour Periodicity."

57. Halberg et al., "From Biologic Rhythms to Chronomes Relevant for Nutrition."

58. Prerau, *Seize the Daylight*.

country cousins hope to abolish this custom.[59] This urban-rural schism may be explained in part by realizing that rhythms in the country may not be as easily shifted as those in the city, as when dairy farmers from Switzerland to Wisconsin complain that their cows cannot, from one day to the next, simply produce milk an hour earlier or later.[60] The barnyard, like all agricultural enterprises, runs by a clock set initially by planetary motion, and only secondarily by the timepiece in Greenwich. In defense of the critics of DST, it seems that a simple one-hour clock shift is not so trivial when we read in Matthew Walker's *Why We Sleep* that numbers of heart attacks spike on the day after clocks are changed.[61]

Another illustration of collective desynchrony stems from various timetables and calendars that have been developed by relying on different elements of the solar system. One can point to the Julian calendar (fine-tuned in 1582 by the Gregorian Calendar) that requires periodic "leap years" to bring days and seasons into alignment. Although one does not get jet-lagged on February 29, this added day every fourth year ramifies into myriad consequences, from anomalous birthdates to higher February energy bills to salaried employees working every fourth year an extra day for free. Such socially imposed time shifts, whether measured in hours or days, produce other consequences, as when switching between calendars based on different astronomical formulations. The Hebrew Calendar relies on twelve lunar months to form a 360-day year, with "leap months" being added in seven out of nineteen years to keep holidays aligned with seasons. Passover occurs on the fifteenth day of the seventh lunar month in repeating nineteen year cycles.[62] But marking Passover (as well as Easter) on a Gregorian calendar produces a seemingly random pattern of springtime dates across the years, leading to desynchronies for people linking their activities to both Hebrew and Gregorian calendars. Similarly, marking Christmas on Islamic, Chinese, or Aztec calendars produces a clustered but seemingly random occurrence of dates from one year to the next, with complicated algorithms being required to translate between these calendars. This diversity of ways to mark time and the complexity of shifting between them means that a globalizing world has faced deep challenges synchronizing its day-to-day schedule. Container ships wait empty, digital networks shut down, and wars break out because of the different ways of adding up lunar orbits and earth rotations to make an annual cycle.

Time lags also present special challenges as well as special opportunities to seafarers. Sailing toward the Americas, European ship navigators discovered that high noon (when the sun shines at its zenith) would shift later with each new day when traveling westward. High noon in London is not the same clock time as high noon partway across the Atlantic, and indeed navigators realized that by measuring the exact time difference

59. "Daylight Saving Time," 13; Phaneuf, "Five Things Everyone Should Know."
60. Wahl, "Zeitumstellung."
61. Walker, *Why We Sleep*, 169.
62. Rappenglück et al., *Astronomy and Power*.

between two zeniths, they could calculate the number of longitudinal degrees they had traveled. Zenith lag could therefore be translated into distance. One twenty-fourth of the earth's 360 degrees means that every hour of time difference between one's current and former positions represents 15 degrees across a globe. Boston's separation from London by 4.73 hours of solar time represents 71 degrees of distance around the earth. As historian Dava Sobel recounts, the race was on in the 1700s to devise a precision time piece that could be set at one's departure and then carried on shipboard to measure precise hours, minutes, and seconds of one's zenith lag, and so provide a good estimate of distance traveled.[63] John Harrison's chronometer of 1735 set a new standard for accurately measuring desynchrony. Even though most seafarers by the late 1800s set their prime meridian at Greenwich, the French maintained their own prime meridian through Paris, and did not officially adopt the London standard until 1914. French seafarers were not more desynchronous than everyone else, but they did measure their zenith lag from a different reference line. One might generalize that ship travel helped establish prime meridians, train travel established time zones, air travel established international datelines, and space travel established earth days. All were outgrowths of the goal of comparing times between distant places on a spinning planet.

Poor Man's Jet Lag

One sees that time desynchronies were a serious human challenge even before air travel was born. Beyond problems presented by translating between calendar conventions and clock comparisons, the effects of desynchrony were even more widely manifested when industry began demanding round-the-clock workforces. With turbines powered by incessant streams of water or the burning of coal, factories could harness labor at all hours of day and night. Once a steel refinery or a textile mill had been built, greater efficiencies and bigger profits could be made by paying workers to take turns stoking fires, twisting dials, and shaping ingots. Although night work had always been needed to guard castle walls and protect the flock, or to comfort the sick and steer sailing ships, the industrial revolution promoted greater independence from the sun's rays. The modern workshop favored continuous labor measured in shifts throughout the day and throughout the year, or as Lewis Mumford explained, "The clock, not the steam engine, is the key-machine of the modern industrial age."[64] The day's parceled-out schedule came to be known as *shift work*. Labor no longer lasted from sunrise to sunset, but could be divided into equal and repeating periods with little regard to daylight or society's own cycles. When a person switched a work schedule from day to night, that worker experienced massive circadian disruption without traveling anywhere.

Although working one-half—and eventually in most countries, one-third—of every twenty-four-hour day improved the lives of many workers while providing a steady

63. Sobel, *Longitude.*

64. Mumford, *Technics and Civilization*, 14.

wage, those who labored by nighttime would end their shift confronted by bright sunlight and city noise when seeking quiet slumber after work, leading them to lose track of the rest of society who lived by the sun. As one labor advocate warned in 1918, the night shift is harmful "since it forbids rest at the time when Nature calls for sleep."[65] Leaving many workers irritated and isolated, the night shift was always the least desirable time to work, and so was usually reserved for apprentices, immigrants, or other second-class workers. Labor laws aimed to provide fairer worker treatment, as by providing higher wages to night shifters or else allowing them to work fewer hours for the same pay; in some countries, children and women were eventually barred from working night shifts, except in certain lines of work such as hospitals.[66] The other compensatory method for dealing with unpopular shifts was to take turns, such that factory or military divisions would rotate their workers in and out of these shifts.[67] Industrial economists put great efforts into devising schedules that efficiently and fairly distributed this *graveyard watch* (or *shift*), a term used by British and American mariners since the late 1800s, and probably derived from the Gaelic night spirit, *Faire Chlaidh*, who in darkness kept watch over the graveyard.[68]

Instead of periodically rotating workers to the following shift after just one or a few days—for that soon exhausted workers—some factory owners maintained workers on the same shifts for a week or a month, and then rotated them to subsequent shifts in the next session, with the third shifts happening in the following session (fig. 4). Submarine captains established more complicated routines, rotating sailors four hours on duty, then eight hours off (or six hours on, then twelve hours off), and then pushed this routine forward or backward four to six hours with each new day.[69] But no matter the schedule, drained, dysrhythmic shift workers continued to labor in factories, mines, bakeries, fire stations, post offices, truck stops, air traffic control towers, convenience stores, and wherever else round-the-clock schedules became the norm.[70] By the 1960s, statistics show that some 24 percent of the US labor force, 17 percent in Norway, and 12 percent in Switzerland were working shift schedules.[71] Thirty-two percent of employees in Detroit and 13 percent in New York were spending their working hours in night shifts.[72] Such numbers reveal not only that shift work was distributed unequally across nations and cities, but that blue-collar workforces were saddled with disproportionately larger shares of this kind of work. Over the next decades, the occupational hardship of *Poor Man's Jet-Lag*, also called *Social Jet Lag*, continued to increase in many nations, even in labor-friendly France.

65. Edwards, "An Address on Industrial Diseases," 97.
66. "H.R. 15651," 548.
67. *Twelve-Hour Shift in Industry*.
68. Campbell, *Superstitions of the Highlands and Islands of Scotland*, 242.
69. Fletcher et al., "Work at Sea."
70. Maurice, *Shiftwork*, 4–9.
71. Mott et al., *Shiftwork*, 1.
72. Luce, *Body Time*, 43.

Assignment	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	
Morning shift	A	A	A	A	A	B	B	B	B	B	C	C	C	C	C	
Afternoon shift	B	B	B	C	C	C	C	C	A	A	A	A	A	B	B	
Night shift	C					A					B					
Days off		C	C	B	B		A	A	C	C		B	B	A	A	etc.

Assignment	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	
First and second week:																
Morning shift	A	A	A	A	A	A		B	B	B	B	B	B			
Afternoon shift	B	B	B	B	B			C	C	C	C	C				
Night shift	C	C	C	C	C			A	A	A	A	A				
Days off						B C	A B C						A C	A B C		
Third and fourth week:																
Morning shift	C	C	C	C	C	C		A	A	A	A	A	A		B	
Afternoon shift	A	A	A	A	A			B	B	B	B	B			C	
Night shift	B	B	B	B	B			C	C	C	C	C			A	
Days off						A B	A B C						B C	A B C		etc.

Figure 4. Two different shift work schedules. Adapted from Marc Maurice, *Shift Work: Economic Advantages and Social Costs* (Geneva: International Labour Office, 1975: 130).

A 1983 US congressional hearing led by Albert Gore sought to clarify the problems posed by shift work, before identifying remedies to deal with this challenging schedule. Noting that some 28 percent of Americans were by then laboring in a shift work system, Gore and colleagues called on a range of workers and experts to share their experience and understanding. Nurses, chemical plant workers, airline pilots, and medical personnel were all brought forward. A tire manufacturer described how, after a few years on this schedule, his physical, mental, and social life began to disintegrate, with his story line being repeated from one profession to the next. Psychologists reported on their survey of Maryland police officers whose shift work brought on problems from digestion and anxiety to headaches and sexual dysfunction: "Emotional symptoms exhibited by shiftworkers are associated with *night workers neurosis*." This malady was reported to cause general weakness and insomnia while impairing work performance, increasing accident rates, and heightening alcohol abuse. Although a few shift workers actually preferred the nocturnal life for the special schedule it afforded them, another researcher testified that "the disruption of a shift worker's social and family life is one of the most frequent sources of complaint."[73] A Harvard physiologist noted simply that "we have not faced up to the fact that both insects and mice subjected to these schedules have a 5 to 20 percent decrease in life span."[74] Regarding solutions to the afflictions of shift work, there was general agreement that night work in a modern world would not, and could not, disappear, with so many cogwheels of society requiring round-the-clock attention. Medication, whether as stimulants or depressants, be they coffee or alcohol, were deemed only marginally effective in alleviating symptoms of disrupted circadian rhythms, and often made things worse. The only concrete recommendations agreed on at the hearing were that workers were better off rotating to later rather than to earlier

73. "Biological Clocks and Shiftwork Scheduling," Hearings, 238, 309, 310, 402.
74. "Biological Clocks and Shiftwork Scheduling," Report, 3.

shifts (from day-to-evening-to-night shifts), rather than the reverse, and that they should maintain their shifts for at least three weeks before rotating to a new shift. Otherwise, concluded the committee, for finding better ways to live with shift work, more research was needed.

A few professions have nonetheless managed to circumvent night shifts in innovative ways. In the field of teleradiology, board-certified radiologists read night-time X-rays via the internet from eight time zones away, thereby allowing them to follow healthy and normal lives in Sydney or Zurich while covering nocturnal emergencies in the United States. Similarly in the financial world, a stockbroker focusing on the Singapore market may find it advantageous to live somewhere else on the globe, so as to utilize one's home time zone to get a jump on stock prices while fully alert.[75] But for the rest of the work-a-day world that does not labor via satellites, night shifts remain a punishing reality. Only by 2014 did the US Occupational Safety and Health Administration (OSHA) officially acknowledge that "workers generally will not acclimate to night work, and sleep patterns will generally be disrupted so the non-work periods do not provide full recovery, resulting in sleep deprivation."[76] Meanwhile, the negative consequences of occupational dysrhythmia are being manifested all around us. Extreme pilot fatigue during the Berlin Airlift, enormous loss of life in building the Aswan Dam, the nuclear meltdown at Three-Mile Island, the massive chemical disaster at Bhopal, and the oil spill of the Exxon Valdez have all been blamed in part or in full on the dysfunctions produced by shift work.[77] Those who suddenly switch work schedules are pushed four, six, eight, or more hours off their bodily cycles, plunging them into poor judgment and impaired performance. Although experts say a person's physical capabilities can be temporarily resilient to circadian stress, one's mental and intellectual facilities suffer considerably.[78] Our modern world threatens the romance of chronophilia.

Seasonal Dysrhythmia

Although shift work disrupts one's daily rhythm, other types of activities can disrupt monthly or yearly rhythms, resulting in other serious health consequences. For instance, by rapidly moving north or south across long distances, time lag can be gauged in seasons rather than hours. Instead of disrupting circadian rhythms, the trans-latitudinal traveler can disrupt circannual rhythms. Thus a traveler undergoes a one-hour lag by rapidly moving 15 degrees west or east, yet by rapidly moving 23 degrees north or south, a traveler can enter a new *season*, experiencing a three-month circannual shift since seasons are produced by the earth's 23-degree axial tilt in its orbit. When flying from London to Lapland, for example, one moves to a colder season and in winter witnesses

75. Kay, "The Advantages of Dwelling in a Decent Timezone."

76. "Extended Unusual Shifts," Occupational Safety and Health Administration, 2014, www.osha.gov/OshDoc/data_Hurricane_Facts/faq_longhours.html (accessed August 13, 2017).

77. Grugle, "Asleep at the Assembly Line"; Stanbridge, "Fatigue in Aircrew Observations"; Mossallam, "We Are the Ones Who Made This Dam 'High'!"

78. US Congress, Office of Technology Assessment, *Biological Rhythms*.

less sunlight with the sun orbiting lower on the horizon. It might be said that north–south flights cause "seasonal lag," which might be diagnosed as Seasonal Affective Disorder (SAD). Sufferers of SAD may experience numbing depression though some find relief by exposing themselves to longer (or stronger) artificial light.[79] SAD is not just a modern medical condition but has existed ever since people traveled rapidly north or south, arriving quickly to unfamiliar sunlight and temperature regimes. The ship doctor of the 1897 Belgian Antarctica expedition, Frederick Cook, described how his crew members would become emotionally and physically depressed at those high latitudes, finally naming their malaise "polar anaemia."[80] Psychologists also diagnose so-called summer SAD, which occurs less frequently than its winter counterpart but strikes the unsuspecting northerner who flies to the tropics and becomes drained by sun exhaustion. One realizes that sudden jumps in latitude, like jumps in longitude, usher in disruptions to bodily rhythms.

While a whole day is generally needed to adjust to every hour of time-zone change, one can only speculate on how long one requires to adjust to a sudden change in seasons. Twenty-three degrees of travel along a north–south longitude line is a ground distance of 1,600 miles. It follows that a person traveling this far north (or south) in *less* than three months is moving faster than seasons change, and so may suffer seasonal lag, physically and psychologically. While not many people can walk faster than seasons change, taking a ship, train, or dirigible easily allows them to transition quickly from summer to fall, or in longer routes, from summer to winter. Each spring, traditional Kazaks migrated by horseback northward across the Asian steppe some six hundred miles in a journey of horizontal transhumance that allowed them to chase the seasons and follow resource abundance;[81] yet by lasting several weeks their journey across the steppes softened seasonal disorientation. Similarly, vertical transhumance finds Austrian cow herders moving up and then down the mountainside according to season, serving to maintain themselves and their animals at fairly constant light and temperature regimes, possibly promoting seasonal desynchrony. But one must travel rapidly up and down or north or south to produce a strong seasonal lag. Such seasonal delerium seems to have played a part in Nobile's second dirigible flight to the North Pole that ended in a crash on the ice, stemming from pilot exhaustion and the disorienting twenty-four-hour sunlight of high-latitude summers.[82]

Beyond disrupted seasonal rhythms, one wonders if people can suffer from disrupted monthly rhythms. Since many creatures apparently experience cycles linked to the moon, one may expect that humans experience *circalunar* cycles: after all, certain fish prefer to spawn and honey bees prefer to swarm by the light of the full moon, so

79. Wehr et al., "Contrasts between Symptoms."
80. Cook, *Through the First Antarctic Night*, 303.
81. Shnirelman et al., "Hooves across the Steppes," 136.
82. Bendrick et al., "Human Fatigue," 1.

that artificial nightlight can induce or disrupt these behaviors.[83] Not surprisingly, many observers have assumed a causal link between human menstrual cycles and lunar orbits, since the former averages twenty-eight and the latter twenty-nine days. But the scientific answer is that menstrual and lunar cycles revolve independently of each other, showing correlative but not causative relationships.[84] There is evidence, nonetheless, that menstrual cycles are dependent on seasonal rather than monthly cues, since the menarches, or women's first menstrual onset, occurs more commonly in summer, continuing thereafter on average twenty-eight-day (but widely varying) cycles. Still, the onset of a summer menarches is probably more cultural than cosmic, since a person's health and so timing of menarches has been linked to such variables as dietary practices, timing of festivals, and family income.[85] Other observations show that industrializing societies witness menarches occuring earlier in a person's life than they did a century ago—by a month or a year—apparently reflecting faster human maturation and probably arising from myriad cultural factors.[86] To reiterate Halberg's insight, our bodily rhythms are shaped, but not determined, by our DNA and the solar system.[87] The field of "social physics" had its heyday with Auguste Comte and Adolphe Quetelet a century and a half ago.[88]

There is little question that modernity has ushered in a range of activities for shifting or distorting human biological rhythms, and not just those happening by the day, month, or year. In our present age we may experience the widest number of desynchronies simply by moving indoors. Once inside our shelters, we light a candle and kindle a fire (or turn on a light and click on the furnace), lengthening daylight and switching seasons in an instant. Indeed much human ambition has been dedicated to modifying the timing and duration of daylight and seasons through technologies, so that our climate-controlled homes promote circadian and circannual shifts on a grand scale. Not only are we modestly but perpetually jet-lagged—with our circadian rhythms requiring daily fine-tuning by genes, society, and the sun—but we moderns now living in the Anthropocene are often out of synch with our primordial rhythms since we have been so successful at creating virtual *Zeitgebers*, those "time-givers" that operate independently from the solar system, be they motion-activated streetlamps or chiming smart phones. Ben Franklin's stove maintained eternal springtime in the home despite fluctuating temperatures outside; Thomas Edison's light bulb proved a powerful tool against winter doldrums by lengthening the shortest days. Through our success in constructing our own niches, we are living beyond the bounds of many of life's rhythms: modernity's accoutrements are the biggest disruptor of our biological clocks. As one response, counterculturists may

83. McDowall, "Lunar Rhythms in Aquatic Animals"; Rich and Longcore, *Ecological Consequences*, 269.
84. Reinberg, "Aspects of Circannual Rhythms in Man."
85. Cutler, "Lunar and Menstrual Phase Locking."
86. Lee et al., "A Study of Menstruation of Korean Adolescent Girls in Seoul," 204.
87. Roenneberg and Aschoff, "Annual Rhythm of Human Reproduction."
88. Donnelly, *Adolphe Quetelet, Social Physics, and the Average Men of Science*.

seek to restore nature's cycles and reconnect to their vestigial rhythms. Escaping the city for a week or a year gives them the chance to reset some of their dysrhythmia—to begin reconnecting with their chronophilia. Henry David Thoreau was someone who sought to get away from the *zeitgebers* of our age. From his cabin in the woods Thoreau mused, "If a man does not keep pace with his companions, perhaps it is because he hears a different drummer. Let him step to the music which he hears, however measured or far away."[89]

Constructing the Bodily Clock

Acclimatization has been the project since the eighteenth century of pushing a plant or animal to grow in a place and climate that is not quite its own. With a bit of coercion, selection, and luck settlers sometimes found that they could make their favorite beasts and crops flourish in a new land, as when British colonists in New Zealand acclimatized merino sheep to their new home.[90] On the other hand, *entrainment* has been the project of pushing plants, animals, and humans to follow schedules or rhythms that are not their own. From chickens laying eggs more frequently, to wheat germinating earlier in spring, to inducing women to give birth on a preferred day or hour, traditional rhythms have been entrained and retimed. The ticktocks are sped up or slowed down, depending on need or taste. Whereas acclimatizers adjust to new climates, entrainers create new rhythms. Entrainers feel that time's cycle, perhaps more than time's arrow, pervades the tissue of living systems and can be modified for good purpose.

There is also the warping of time, whereby one's chronological perception depends on the speed or position of the observer. In Einstein's famous thought experiment, the rider in a streetcar traveling away from a clock tower at the speed of light observes that the tower's time stands still while the streetcar's time moves forward normally. Even if time's relativity can be described mathematically, it is easy to realize that time can travel at different speeds depending on our state of animation. When engaged in a good book or good conversation, the hands on a clock spin by, but when bogged down by cumbersome chores or other undesirable events, time mysteriously slows down even when a clock's mechanical hands appear to move uniformly. As Christopher J. Lee asserts, "Time is not so much determined by a wristwatch as it is felt."[91] Others point out that most of us can be classified into *morning* or *night* persons, whereby some of us do our best under a rising sun, whereas others perform optimally after the sun sets. Yet these two *chronotypes* may be less affected by the position of the sun than they are to each other, with people preferring certain hours of the day because others prefer other hours. Explains Thomas Luckmann, "The synchronization of two streams of consciousness can only come about when the individuals are situated in bodily presence of one another."[92] Celestial bodies therefore revolve with the precision of a metronome, yet our internal clocks are

89. Thoreau, *Walden*, 317.
90. Ritvo, "Going Forth and Multiplying."
91. Lee, *Jet Lag*, 20.
92. Luckmann, "Constitution of Human Life in Time," 156.

continually being entrained by other people's clocks. This social dependency of rhythm may help explain why certain people perceive the passage of time so differently. Benjamin Whorf famously declared that the Hopi sense of time was quite unlike that of their European neighbors since the Hopi apparently had no words in their vocabulary to denote the future or the past.[93] Even if subsequent linguists have revealed subtle tenses that indicate *before* and *after* in Hopi verbs, Hopi chronophilia provides a striking contrast to that of the Western social scientists who came to study them. As literary scholar Susan Brantly points out, the lesson to be learned here from the Hopi is to question the inevitable organization of time into past, present, and future: "Organic time is just as much a construction as linear time."[94]

Lifetime's Rhythm

In his textbook about biological rhythms, John D. Palmer reports on data that tracks the month and hour when people are most likely to die. Since people are not born uniformly across the year—with September 16 being the most common birthdate—one might expect that people also die in nonrandom patterns. It turns out that in the northern hemisphere, people are most likely to succumb in January during the early hours of 5 to 6 a.m. In the southern hemisphere, they are also most likely to die in early winter mornings, which in the Down Under occurs in July.[95] Yet leaving aside how temperature or weather, tradition or festival, sun or moon may contribute to the exact moment when a person expires, one realizes that human lifespan is itself a rhythm of the universe. Humanity's demographic waves roll across the earth in circa twenty-five-year generations, with average life expectancy now being about three such generations. Modified by natures and nurtures, place and time, humanity has witnessed its lifespan increase in almost all countries over the last century, with larger increases in developing than developed countries. The average world lifespan is now about seventy to eighty years, up decades from what it was a hundred years ago.[96] Before the industrial revolution, human longevity remained remarkably constant for centuries, bobbing around thirty-five years.[97] Lifespan is apparently a biological clock which we have desperately sought to prolong despite various adverse side effects, as when we outlive our joints or our eyes or our teeth, which may age more quickly than the rest of our bodies. Because of differential aging, we undergo heterogeneous desynchrony in old age. At some point, our various internal clocks begin ticking off in their own directions and can no longer be resynchronized. Following 200 millennia of human evolution, our bodies are naturally

93. Whorf, "An American Indian Model of the Universe."

94. Brantly, *Historical Novel*, 30.

95. Palmer, *Introduction to Biological Rhythms*, 154–55.

96. "Global Health: Today's Challenges." *World Health Report*, www.who.int/whr/2003/chapter1/en/index1.html (accessed October 12, 2017).

97. Roser, "Life Expectancy."

programmed and culturally conditioned to eat, sleep, and think in roughly daily cycles and to expire in somewhat less than centurial cycles.

In a curious piece of nineteenth-century garden literature that celebrates Linnaeus's flower clock—that botanical timepiece that marks the hour by a sequence of blossoming flowers—John Hutton Balfour muses that the human lifespan itself might be considered a deity's clock. By marking increments of time

> we mortals may be a flower-clock for higher beings, when our flower-leaves close upon our last bed; or sand-clocks, when the sand of our life is so run down that it is renewed in the other world; or picture-clocks, because, when our death-bell here below strikes and rings, our image steps forth from its case into the next world. On each event of the kind, when seventy years of human life have passed away, they may perhaps say, "What! Another hour already gone? How the time flies!"[98]

The geographer Yi-Fu Tuan has proposed that our relationships with familiar landscapes and natural spaces can be encapsulated by *topophilia*, or love of place. Psychological attachment to a specific location, Tuan argues, expresses itself from birth to death, being manifested in the ways that we build our houses, cook our meals, and interact with one another. Our homes and shelters "become a symbol of psychic wholeness, a microcosmos capable of exercising a beneficent influence on the human beings who enter the place or live there." Feelings of topophilia "include all of human being's affective ties with the material environment."[99] Yet along with this attachment to place, one must acknowledge our attachment to rhythm. We are sensitive to rhythms of time even more than particular moments in time. Far from emanating randomly, life's rhythms arrive in recurring waves, such as the galactic pulsars that beat with such regularity that we can set our earthly clocks by them. Our attachment to rhythm means that our lungs respire twelve times and our hearts beat seventy-five times each minute. The earth also respires with rhythmic regularity, with Gaia gushing out atmospheric oxygen each spring. Cosmic clocks combine with physiologic clocks to synchronize the molecular pulses that course through our cells. Orbits of the earth and moon, together with leaves falling in autumn, salmon returning to their natal streams, waves rolling up the beach, and humans living out their lives, are all manifestations of our ticking universe. For several days after a transoceanic flight, our former time zone's rhythms remain part of us, and we part of them. As Pico Iyer explains, a repeatedly and severely jet-lagged person may well experience "not a *Where am I?* dream, which you'd expect, but a *Who am I?* dream."[100] Rapidly transporting our bodies across places on a spinning earth produces disharmonies that are spatial as well as temporal, reflecting our dependencies on *topophilia* as well as *chronophilia*.

98. Balfour, *Phyto-Theology*, 143.
99. Tuan, *Topophilia*, 18, 93.
100. Iyer, *Global Soul*, 112.

Having explored some experiences with desynchrony, we can now realize that our attachment to rhythm, our love of familiar time, is a guide that helps steer us throughout the day and year. Just as residents inside the confines of the Alhambra sensed the hour of the day according to the sequence of odors that wafted throughout the palace, we experience our own diurnal rhythms when greeted each morning by a steaming coffee, then propelled through the day by sugared installments, downshifted in evening with a glass of wine, and finally soothed into bed by a chamomile tea. One event logically flows to the next, with our bodies responding accordingly. Should we interrupt our routine, or miss a ritual beverage, we do not feel our best or cannot fall asleep. But it is not merely the absence (or excess) of caffeine that throws us, for there are also innate bodily stimulants that combine with those we consume. The endorphins that bathe our tissues and make us feel our finest typically peak in the morning after falling to a nadir at night; yet we can also elevate these chemical levels with modest exercise.[101] Cultural, physiological, and cosmological stimuli, working through holistic natureculture responses, produce the chemical fluxes of chronophilia. We order our days and our lives along a sequence of events, and suffer if that sequence is rearranged, distorted, or disrupted. We are creatures of chronological habit.[102]

If in the end we earthlings finally carbonate our atmosphere, and board rockets to colonize Mars, we will certainly miss the azure oceans, the white sand beaches, the grasslands, the tropical forests, the delicate orchids, the great cities, the cultivated scapes—or what is left of them. The red, cold gravels that will greet us on the Martian planet, presumably viewed from inside our insulated spacesuits or through the picture windows of our heated homes, will never match the greens, blues, and browns of our home planet. We may never be able to acclimatize ourselves to that Martian landscape, an utterly alien *topos*. But our *chronos* will feel some familiarity on our adopted planet. Astronomers reveal that the Martian day lasts 24.6 hours, meaning that Martian nighttimes and daytimes are nearly the same as those on Earth, allowing us to easily entrain ourselves to get a comfortable night's sleep—even if the sun is further away and forms a smaller disc in the heavens. On Mars, we will also experience our usual seasons, since its axis tilts at 25 degrees and is amazingly close to the Earth's own 23.5-degree tilt. And when we board our hovercraft to visit a different part of the Red Planet, flying from one Martian time zone to the next, our chronophilia means that we may feel right at home when we suffer typical jet lag, and perhaps even seasonal lag if we fly north and south, just as we did on Earth, since these two planets share so many celestial mechanics. Perhaps we need only acquire wristwatches that keep Martian time (in hours that lasts 61.6 earth minutes), so that we can tell when it's high noon on our new home.[103] A glance on

101. See McMurray, Hill, and Field, "Diurnal Variations."

102. For more explorations of temporal notions relating to natureculture, see Fitz-Henry, "Multiple Temporalities."

103. "Watchmaker with Time to Lose."

eBay reveals that a few clockmakers already sell Mars-accurate wristwatches, stemming from the demand of NASA engineers who need to keep track of their Martian rovers.

Yet despite all this astronomical coincidence, we displaced earthlings will have a much harder time entraining our bodies to follow the Martian year of 687 earth days. Each year and each season will last almost twice as long as what we are used to, making it hard on our bodies and on our minds to go through life at roughly half our accustomed pace, since living to seventy-five on Earth would mean making it to only forty on Mars. Deities who rely on human lifespans to mark off time may have to reset their own clocks if we take up residence on Mars, since every planet runs by its own heliogeophysical parameters. Barring a sudden deceleration of our own genetic and cultural rhythms, our lifespan will always remain attached to our home planet, however distant and however climate changed. In the end, chronophilia means that we humans will always feel foreign on any other planet. Space travelers beware that no matter how hard we try, many of our own ticks and tocks will always emanate from our own tilting, rotating, and revolving Earth. We can remake, reset, and entrain our earthly rhythms, but we will always live with them from our first days in the womb.

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References

Altman, Lawrence. *Who Goes First? The Story of Self-Experimentation in Medicine*. Berkeley: University of California Press, 1987.

Arendt, Josephine, and Vincent Marks. "Can Melatonin Alleviate Jet Lag?" *British Medical Journal* 287 (1983): 426.

Aschoff, Jürgen. "Circadian Rhythms in Man." *Science* 148 (1965): 1427–32.

Baker, Alan. n.d. "C-130 Airlift in Vietnam." vietnamairlift.com/index.html (accessed July 19, 2017).

Balfour, John Hutton. *Phyto-Theology; or, Botanical Sketches Intended to Illustrate the Works of God in the Structure, Functions, and General Distribution of Plants*. London: Johnstone and Hunter, 1851.

Bendrick, Gregg, Scott Beckett, and Elizabeth Klerman. "Human Fatigue and the Crash of the Airship *Italia*." *Polar Research* 35, no. 1 (2016): 1–16.

"Biological Clocks and Shiftwork Scheduling." Hearings before the Subcommittee on Investigations and Oversight, Ninety-Eighth Congress, March 23–24, 1983. Washington, DC: GPO, 1983.

"Biological Clocks and Shiftwork Scheduling." Report Prepared by the Subcommittee on Investigations and Oversight. Washington, DC: GPO, 1984.

Brantly, Susan. *The Historical Novel, Transnationalism, and the Postmodern Era: Presenting the Past*. New York: Routledge, 2017.

Brown, Arthur. *Flyng the Atlantic in Sixteen Hours*. New York: Stokes, 1920.
Brown, Frank. “Living Clocks.” *Science* 130, no. 3388 (1959): 1535–44.
Butler, Alex. “Beat the Jetlag.” Lonely Planet. www.lonelyplanet.com/news/2016/09/23/hotel-guests-sleep-better/ (accessed May 1, 2018).
Caldwell, Dan, and William Hocking. “Jet Lag: A Neglected Problem of Modern Diplomacy?” *Hague Journal of Diplomacy* 9, no. 3 (2014): 281–95.
Cambrosio, Alberto, and Peter Keating. “The Disciplinary Stake: The Case of Chronobiology.” *Social Studies of Science* 13, no. 3 (1983): 323–53.
Campbell, John. *Superstitions of the Highlands and Islands of Scotland*. Glasgow: MacLehose, 1900.
Campbell, Mark, and Victor Harsch. *Hubertus Strughold: Life and Work in the Field of Space Medicine*. Neubrandenburg, Germany: Rethra, 2013.
Comperatore, Carlos, and Gerald Krueger. “Circadian Rhythm Desynchronosis, Jet Lag, Shift Lag, and Coping Strategies.” *USAARL Report* No. 90–14. Fort Rucker, AL: Biomedical Applications Research Division, 1990.
Cook, Frederick Albert. *Through the First Antarctic Night, 1898–1899: A Narrative of the Voyage of the “Belgica” among Newly Discovered Lands and over an Unknown Sea about the South Pole*. New York: Doubleday and McClure, 1909.
Cutler, Winnifred B. “Lunar and Menstrual Phase Locking.” *American Journal of Obstetrics and Gynecology* 137, no. 7 (1980): 834–39.
Daan, Serge. “A History of Chronobiological Concepts.” *Protein Reviews* 12 (2010): 1–35.
Darwin, Charles. *The Power of Movement within Plants*. London: Murray, 1880.
“Daylight Saving Time.” Parliament of Australia, Research Note 13, December 4, 2006.
de Mairan, J. J. “Observation botanique.” *Histoire de l’Académie royale des sciences avec les mémoires de mathématique et de physique tirés des registres de cette Académie* (1729), 35–36. www.bibnum.education.fr/sciencesdelavie/biologie/observation-botanique/ (accessed July 20, 2017).
Donnelly, Kevin. *Adolphe Quetelet, Social Physics, and the Average Men of Science, 1796–1874*. Pittsburgh, PA: University of Pittsburgh Press, 2016.
Dubin, Alesandra. “This Is the Insane Number of Flyers in the Air at a Given Moment.” www.bravotv.com/blogs/how-many-airplanes-fly-at-the-same-time/ (accessed May 19, 2017).
Edwards, J. Watkins. “An Address on Industrial Diseases.” *British Medical Journal* 2, July 26, 1916.
Fitz-Henry, Erin. “Multiple Temporalities and the Nonhuman Other.” *Environmental Humanities* 9, no. 1 (2017): 1–17.
Fletcher, N., W. P. Colquhoun, P. Knauth, D. DeVoll, and R. Plett. “Work at Sea: A Study of Sleep, and of Circadian Rhythms in Physiological and Psychological Functions, in Watchkeepers on Merchant Vessels.” *International Archives of Occupational Environmental Health* 61, nos. 1–2 (1988): 51–57.
Flight, “Atlantic Journey.” July 11, 1946, 29–32.
Foster, Russell, and Leon Kreitzman. *Rhythms of Life*. London: Bookmarque, 2004.
Foster, Russell G., and Leon Kreitzman. *Circadian Rhythms: A Very Short Introduction*. Oxford: Oxford University Press, 2017.
Fox, Stephen. *The Ocean Railway: Isambard Kingdom Brunel, Samuel Cunard, and the Revolutionary World of the Great Atlantic Steamships*. London: Harper, 2003.
Grugle, Nancy. “Asleep at the Assembly Line: Shiftwork, Sleep Deprivation, and Industrial Accidents.” Robson Forensic. www.robsonforensic.com/articles/shift-work-sleep-deprivation-and-industrial-accidents-expert-article (accessed August 16, 2017).
Halberg, Franz. “Physiologic Twenty-Four–Hour Periodicity; General and Procedural Considerations with Reference to the Adrenal Cycle.” *Zeitschrift Vitamin- Hormon-und Fermentforschung* 10 (1959): 225–96.
Halberg, Franz, Erhard Hus, and Germaine Cornélissen. “From Biologic Rhythms to Chronomes Relevant for Nutrition.” In *Not Eating Enough: Overcoming Underconsumption of Military Rations*, edited by Bernadette M. Marriott, 361–72. Washington, DC: National Academy Press, 1995.

Hall, Marcus. "Can Bats See with Their Ears? Lazzaro Spallanzani and Eighteenth-Century Animal Sensation." MA Thesis, University of Wisconsin–Madison, 1989.
Hauty, George, and Thomas Adams. "Pilot Fatigue: Intercontinental Jet Flight." Oklahoma City: Federal Aviation Agency, 1965.
Hiam, C. Michael. *Dirigible Dreams: The Age of the Airships*. Lebanon, NH: University Press of New England, 2014.
Iyer, Pico. *The Global Soul: Jet Lag, Shopping Malls, and the Search for Home*. New York: Vintage, 2000.
Johnson, Andi. "'They Sweat for Science': The Harvard Fatigue Laboratory and Self-Experimentation in American Exercise Physiology." *Journal of the History of Biology* 48 (2015): 425–54.
Johnson, James, and Henry Johnson, eds. *The Medico-Chirurgical Review* 12 (1840).
Kay, John. "The Advantages of Dwelling in a Decent Timezone." *Financial Times*, February 9, 2016.
Keeling, Drew. *The Business of Transatlantic Migration between Europe and the United States, 1900–1914*. Zurich: Chronos, 2012.
Kleitman, Nathaniel. *Sleep and Wakefulness*. 1939; repr., Chicago: University of Chicago Press, 1987.
Lafrance, Adrienne. "Sergey Brin's Secret Zeppelin." *Atlantic*, April 27, 2017. www.theatlantic.com/technology/archive/2017/04/sergey-brins-zeppelin/524568/.
Laskowitz, Isidor, Joseph Lynch, G. M. Bain, eds. "Civilian and Military Uses of Aerospace." Special issue. *Annals of the New York Acadey of Sciences* 134, no. 1 (1965): 1–496.
Lee, Christopher J. *Jet Lag*. New York: Bloomsbury Academic, 2017.
Lee, Jin, Byung Yu, Jung Byeon, Kee-Hyoung Lee, Jung Min, and Sang Park. "A Study of Menstruation of Korean Adolescent Girls in Seoul." *Korean Journal of Pediatrics* 54, no. 5 (2011): 201–6.
Lewis, P. R., and Mary Lobban. "Dissociation of Diurnal Rhythms in Human Subjects Living on Abnormal Time Routines." *Experimental Physiology* 42, no. 4 (1957): 371–86.
"Lighter-Than-Air Ships." *Journal of Air Law* 8 (1937): 258.
Linnaeus, Carl. *The Elements of Botany*, translated by Hugh Rose. 1751; repr., London: Cadell, 1775.
Luce, Gay. *Body Time*. Bath, UK: Pitman Press, 1972.
Luckiesh, Matthew. *Artificial Light: Its Influence Upon Civilization*. New York: Century Company, 1920.
Luckmann, Thomas. "The Constitution of Human Life in Time." In *Chronotypes: The Construction of Time*, edited by John Bender and David E. Wellbery. Stanford, CA: Stanford University Press, 1991.
Maitland, Edward, and Rudyard Kipling. *The Log of H.M.A. R34 Journey to America and Back*. London: Hodder and Stoughton, 1921.
Malawwethanthri, Kapila. "Fatigue and Jet Lag: In Search of Sound Sleep." *Seaways* (November 2003): 26–28.
Maranzani, Barbara. "Wiley Post Makes History." *History Stories*, 2013. www.history.com/news/wiley-post-makes-history/ (accessed May 1, 2018).
Marx, Leo. *The Machine in the Garden: Technology and the Pastoral Ideal in America*. New York: Oxford University Press, 1964.
Maurice, Marc. *Shiftwork: Economic Advantages and Social Costs*. Geneva: International Labor Office, 1975.
McDowall, R. M. "Lunar Rhythms in Aquatic Animals: A General Review." *Tuatara* 17, no. 3 (1969): 133–43.
McMurray, Robert, David Hill, and Kelly Field. "Diurnal Variations of Beta-Endorphin at Rest and after Moderate Intensity Exercise." *Chronobiology International* 7 (1990): 135–42.
Mossallam, Alia. "We Are the Ones Who Made This Dam 'High!'" A Builders' History of the Aswan High Dam." *Water History* 6, no. 4 (2014): 297–314.
Mott, Paul, Floyd Mann, Quin McLoughlin, and Donald Warwick. *Shiftwork: The Social, Psychological, and Physical Consequences*. Ann Arbor: University of Michigan Press, 1965.
Mumford, Lewis. *Technics and Civilization*. Chicago: University of Chicago Press, 1934.
NASA Technical Reports Server (NTRS). *Information Services for Comparative Analysis of Biorhythm Research*. Washington, DC: AMES, NASA, 1972.

New York Times. "Jet-Shrunk World Awaits Tourist." March 1, 1959.
New York Times. "Long Hauls Are a Strenuous Part of the Long Season." April 17, 1966.
Nobile, Umberto. *My Polar Flights: An Account of the Voyage of the Airships* Italia *and* Norge. London: Frederick Muller, 1961.
Palmer, John D. *An Introduction to Biological Rhythms*. New York: Academic Press, 1976.
Phaneuf, Daniel. "Five Things Everyone Should Know about Daylight Saving Time." *Grow: Wisconsin's Magazine for the Life Sciences*, spring 2016. grow.cals.wisc.edu/uncategorized/five-things-everyone-should-know-about-daylight-saving-time (accessed May 1, 2018).
Prerau, David. *Seize the Daylight: The Curious and Contentious Story of Daylight Saving Time*. New York: Thunder's Mountain Press, 2005.
Rappenglück, Michael, Barbara Rappenglück, Nicholas Campion, and Fabio Silva, eds. *Astronomy and Power: How Worlds are Structured; Proceedings of the SEAC 2010 Conference*. Oxford: British Archaeological Reports, 2016.
Rasmussen, Nicolas. *On Speed: From Benzedrine to Adderall*. New York: NYU Press, 2008.
Reinberg, Alain. "Aspects of Circannual Rhythms in Man." In *Circannual Clocks: Annual Biological Rhythms*, edited by Eric Pengelley, 423–506. New York: Academic Press, 1974.
Rich, Catherine, and Travis Longcore, eds. *Ecological Consequences of Artificial Night Lighting*. Covelo, CA: Island Press, 2006.
Rijo-Ferreira, Filipa, Daniel Pinto-Neves, Nuno L. Barbosa-Morais, Joseph S. Takahashi, and Luisa M. Figueiredo. "*Trypanosoma brucei* Metabolism Is under Circadian Control." *Nature Microbiology* 2, article no. 17032 (2017).
Ritvo, Harriet. "Going Forth and Multiplying: Animal Acclimatization and Invasion." *Environmental History* 17 (2012): 404–14.
Rodrigue, Jean-Paul. *The Geography of Transport Systems*. New York: Routledge, 2017.
Roenneberg, Till, and Jürgen Aschoff. "Annual Rhythm of Human Reproduction: II. Environmental Correlations." *Journal of Biological Rhythms* 5, no. 3 (1990): 217–39.
Roenneberg, Till, and Martha Merrow. "Entrainment of the Human Circadian Clock." *Cold Spring Harbor Symposia on Quantitative Biology* 72 (2007): 293–99.
Rosendahl, Charles. *What about the Airship? The Challenge to the United States*. New York: Scribner's, 1938.
Roser, Max. "Life Expectancy." ourworldindata.org/life-expectancy/ (accessed May 1, 2018).
Sack, Robert L. "Clinical Practice: Jet Lag." *New England Journal of Medicine* 3624, no. 5 (2010): 440–47.
Sahota, Kohinoor. "In London, Hotels Help Guests Combat Jet Lag." Where Traveler, March 21, 2015. www.wheretraveler.com/london/shop/london-hotels-help-guests-combat-jet-lag.
Sanders, Donald C., Arvind K. Chaturvedi, and Jerry R. Hordinsky. "Aeromedical Aspects of Melatonin—An Overview," Final Report. Washington, DC: US Department of Transportation, Federal Aviation Administration, 1998.
Scanlon, Lynne, and Charles Ehret. *The Cure for Jet Lag*. New York: Back2Press, 2008.
Shnirelman, Victor, Sandra Olsen, and Patricia Rice. "Hooves across the Steppes." In *Horses through Time*, edited by Sandra Olsen, 129–52. Lanham, MD: Rowman and Littlefield, 1996.
Siegel, P. V., Siegfried J. Gerathewohl, and Stanley R. Mohler. "Time-Zone Effects on the Long Distance Air Traveler." Washington, DC: US Department of Transportation, Federal Aviation Administration, 1969.
Sobel, Dava. *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time*. New York: Walker and Company, 1995.
Stanbridge, R. H. "Fatigue in Aircrew Observations in the Berlin Airlift." *Lancet* 258, no. 6671 (1951): 1–3.
Strughold, Hubertus. "Physiological Day-Night Cycle after Global Flight." *Journal of Aviation Medicine* 23 (1952): 464–73.
The Twelve-Hour Shift in Industry. Committee on Work Periods in Continuous Industry of the Federated Engineering Societies. New York: Dutton, 1922.

Thoreau, Henry David. *Walden; or, Life in the Woods* (1854), edited by Jeffrey Cramer. New Haven, CT: Yale University Press, 2004.
Tuan, Yi-Fu. *Topophilia: A Study of Environmental Perceptions, Attitudes, and Values*. New York: Columbia University Press, 1974.
US Congress, Office of Technology Assessment. *Biological Rhythms: Implications for the Worker*. Washington, DC: GPO, 1991.
US Department of Commerce and Labor. *Eight Hours for Laborers on Government Work*. Ann Arbor: University of Michigan Library, 1905.
Vora, Shivani. "Hotels That Help You Fight Jet Lag." *New York Times*, June 27, 2016.
Wahl, Michael. "Zeitumstellung: Bauern wehrten sich heftig." *Schweizer Bauer*, October 25, 2013.
Walker, Matthew. *Why We Sleep: Unlocking the Power of Sleep and Dreams*. New York: Scribner, 2017.
"Watchmaker with Time to Lose." Jet Propulsion Laboratory, January 8, 2004. mars.nasa.gov/mer/spotlight/spirit/a3_20040108.html.
Wehr, T. A., H. A. Giesen, P. M. Schulz, J. L. Anderson, J. R. Joseph-Vanderpool, K. Kelly, S. Kasper, and N. E. Rosenthal. "Contrasts between Symptoms of Summer Depression and Winter Depression." *Journal of Affective Disorders* 23, no. 4 (1991): 173–83.
Wever, Ruetger. "Der Einfluss des Lichtes auf die circadiane Periodik des Menschen." *Zeitschrift fuer medizinische Physik* 3 (1973): 121–34.
Wever, Rüetger. *The Circadian System of Man: Results of Experiments under Temporal Isolation*. New York: Springer, 1979.
"What Is Pilot Fatigue?" *Journal of Aeronautical Sciences* 4 (1939): 194–98.
Whorf, Benjamin L. "An American Indian Model of the Universe." *ETC: A Review of General Semantics* 8, no. 1 (1950): 27–33.
Winfree, Arthur. *The Timing of Biological Clocks*. New York: Scientific American Library, 1987.